Chapter 1
General

1-1. Purpose

This manual provides criteria and guidance for the design of heating, ventilating and air conditioning (HVAC) control systems, and designates the standard control loops to be used.

1-2. Scope

This manual describes frequently encountered control-system loops, provides examples of how these loops are used, and provides guidance and criteria for the design of standard HVAC control systems and standard control panels. This manual does not provide guidance on selecting HVAC systems and does not prohibit selection of system types not included herein.

1-3. References

The following documents form a part of this manual to the extent referenced:

a. Government Publications TM 5-785, Engineering Weather Data.

b. Government Publications TM 5-815-2, Energy Monitoring and Control Systems.

1-4. Policy.

a. Adherence to the standards. The design of the HVAC control systems will not deviate from the standards established in this technical manual, except where the design agency has approved a waiver request.

b. Control-system designer responsibilities. The HVAC control-system designer will be responsible for designing each control system required for the project HVAC systems, and will incorporate the control loops, control-system sequences of operation, and HVAC control-panel layouts, using the symbols, abbreviations, and acronyms designated in this manual. This design responsibility requires producing a design package that includes a specification, a set of drawings, and commissioning procedures for each HVAC control system. The designer will not depend on any HVAC control-system vendor for the design of the HVAC control systems.

c. Control-system vendor compliance. The HVAC control-system vendor will be required by the contract documents to make the system product-specific. The specification will require the HVAC control-system vendor to produce shop drawings, schedules, instructions, test plans, test procedures, commissioning procedures, and other documents showing the application of products to implement the control-system design. The specification will require that the HVAC control-system vendor test the control system and document the test to show that the control system functions as designed, and to commission the control system.

1-5. Control-system designer guidance

a. Control-system loops and control logic. The manual includes descriptions of loops for controlling temperature, humidification, airflow, and duct-system static pressure. In addition, the manual contains control logic for the following:

(1) Scheduling and initiating system operation.
(2) Changes in control modes of operation.
(3) Normal interlocks.
(4) Life-Safety system interlocks.
(5) Special interlocks (such as for freeze protection).

b. Control-system variations. The manual shows some of the possible HVAC-system equipment and control-system variations, and provides guidance and examples to show how the designer can modify control loops and systems for applications not specifically shown. The HVAC equipment and system variations for which control-system guidance is provided include:

(1) Outside-air preheat coils using hot water or glycol.
(2) Outside-air preheat coils using steam.
(3) One-hundred-percent outside air in lieu of outside-air/return-air economizer.
(4) Deleting economizer control.
(5) Return fans.
(6) Exhaust fans.
(7) Humidity controls.
(8) Smoke dampers in HVAC supply-air and return-air ducts.
(9) Override of control of valves and dampers for freeze-protection or smoke-control systems.
(10) Startup and shutdown of HVAC fan systems by external systems such as smoke control.
(11) Variable-speed fan drives.
(12) Combining systems in a common control panel.
(13) Unoccupied-mode space-temperature setback control of HVAC equipment.
(14) Building purge and recirculation modes.
(15) Variations in the use of control valves.

c. Project applicability. The HVAC control systems shown in this manual are applicable to new-construction building projects, building-addition projects, building-renovation projects, and (as further described in chapter 6) building-retrofit projects.

d. Types of HVAC equipment covered. This manual provides control-system guidance for HVAC systems for heating, cooling, humidity control, ventilation and air delivery, terminal units, and small packaged unitary systems. Terminal units include Variable Air Volume (VAV) boxes, duct coils, fan-coil units, unit heaters, gas-fired infrared heaters, and radiators.

e. Exceptions. This manual does not cover systems for HVAC equipment such as boilers and chillers, which usually have controls integral to the equipment.

1-6 Design concept

The guidance contained in this manual adheres to a particular concept for designing HVAC control systems. This concept includes the use of standard control systems that incorporate standard control loops and standard control-system devices. The manual shows which devices are housed in a standard HVAC system control panel. The design concept also includes the use of digital single-loop controllers for the control of air-handling systems and hydronic systems. The use of these controllers for such systems has been tested in the laboratory and in the field.

1-7 Control-system standards

a. Standard instrumentation signals. The HVAC control-system transmitter signals and the single-loop controller signals will be standard instrumentation signals of 4 to 20 milliamperes, which can be readily interfaced with most types of energy monitoring and control systems (EMCS). When required, the controller output signal will be converted to 3 to 15 psig.

b. Actuators. Actuation of valves and dampers for HVAC systems such *as* air-handling units and convertors will normally be by pneumatic actuators. This manual also provides guidance on substituting electric or electronic actuators for pneumatic actuators.

c. Terminal-unit control Systems. Terminal-unit control systems will use only electric or electronic control devices. The foregoing requirement for standard instrumentation signals does not apply to terminal-unit control systems.

d. Standard controller. A single version of an electronic, self-tuning controller (generally known as a digital single-loop controller) will be used as the standard controller for HVAC systems in all applications except for terminal-unit control-system applications. This type of controller has a history of reliable use, and is available from multiple sources as a standard product with the features described for its use in this manual. Using a standard controller will make control systems easier to maintain. The standard controller will accept one analog signal as a process variable input (PV) and one analog signal as a remote setpoint adjustment (CPA) input, and will produce one analog output signal (OUT). The controller will fit in a standard-size panel cutout. A controller of one manufacturer may be replaced by a controller of another manufacturer because several manufacturers produce the same version of the controller.

1-8 Project implementation

a. Impact of other design disciplines on control-system design. Design of HVAC control systems is largely driven by decisions on the overall-building HVAC mechanical and electrical design. Therefore, design of the HVAC control system must be incorporated into the overall design process to ensure adequate consideration of the space requirements for the HVAC control system's mechanical and electrical support services. Early involvement of the HVAC control-system designer in the project can help prevent unfortunate HVAC system design choices that could result in marginally-controllable HVAC systems. The control-system designer's involvement should start with the development of the design concept and continue throughout the design process. The control-parameter criteria (temperature, humidity, pressurization, occupancy schedules, etc.) must be defined for all systems. These criteria are the starting point for the HVAC control-system design. The controller setpoints are shown on the HVAC control-system contract drawings and are based on the HVAC system design criteria. The setpoints are guidance for maintenance of the control systems.

b. Reuse of existing control devices. Renovation and addition projects require extra engineering work in the form of a detailed field survey of existing HVAC control systems to determine if existing control devices can be reused for the project, and, if so, the extent to which they require modification. Devices that use standard 4-20 milliampere of 3-15 psig signals are among those which possibly may be reused. The contract drawings must show control devices that will be reused, replaced, modified, or removed.

c. Locations of control devices. The designer will show the locations of wall-mounted instruments, HVAC control panels and outside air sensors, transmitters, and sunshields on HVAC floor-plan drawings. The designer must show the location of sensing elements and primary measuring devices on the HVAC system drawings. An exception to this requirement is the sensing location of the duct-pressure instrument for the supply-fan pressure-control loop of a Variable Air-Volume system; this sensing location is determined by the installed ductwork configuration. This requirement is intended to ensure that design consideration is given to these details so that the sensing will be proper and accurate, and to provide for clearance and access for maintenance of the control system. The locations of thermometers and pressure gauges should be selected for normal visual access by personnel required to read them.

d. Control-device clearance and access. Control-system elements must not intrude upon the space required for mechanical- and electrical-system maintenance access. The control-system design must be coordinated with the HVAC-system design to provide ductwork access to install sensing elements and transmitters.

e. Location of permanent instrumentation. The location of the permanent instrumentation thermometers, spare wells, and valved outlets for gauges in piping systems must be coordinated with the HVAC system design and must be shown on the HVAC-system contract drawings. Sufficient access space must be provided in the ductwork downstream of each air-flow measurement sensor and array, to allow for a traverse with a portable instrument for calibration purposes.

f. Coordination with electrical-system design. The designer will coordinate the control-system design with the electrical-system design to show power circuits for HVAC control panels, air compressor, and drier.

1-9. Design-package requirements for HVAC control systems

a. Drawings.

(1) The designer will include standard HVAC control-panel drawings to describe control-panel construction and mounting arrangements as shown in chapter 4. These drawings are:

(a) Standard wall-mounted HVAC control-panel arrangement.
(b) Standard HVAC control-panel interior door.
(c) Standard HVAC control-panel back-panel layout.

(d) Controller wiring.
(e) Supply-fan and return-fan starter wiring.
(f) Exhaust-fan and pump-starter wiring.
(g) HVAC control-panel power wiring.
(h) Damper schedule.

(2) Some simple control systems do not require a control panel and would not require panel drawings.

(3) the schematic will show control-loop devices and other permanent indicating instrumentation (such as pressure and draft gauges, thermometers, flow meters, and spare thermometer wells). The indicating instrumentation is intended to permit a visual check on the operation of the HVAC control system.

(4) Control systems for HVAC often require connections to boiler-control systems, chiller-control systems, variable-speed drives, fire-alarm and smoke-detection systems, and EMCS. The schematic and the ladder diagram will show the interface points between field-installed HVAC control systems, factory-installed HVAC control systems, and other control systems.

(5) The ladder diagram will show the relationship of the devices within the HVAC control panel and their relationship to HVAC equipment magnetic starters and other control panels.

(6) The equipment schedule will show the information that the vendor needs to:

(a) Provide instrumentation of the calibrated ranges.
(b) Select control valves and associated actuators.
(c) Adjust the control-system devices for sequencing operations.
(d) Configure the controller parameters, such as setpoints and schedules.
(e) Set the control-system time clocks.

(7) The interior-door layout will show the controllers, switches, pilot lights, pneumatic receiver gauges, current signal-to-pneumatic signal devices, and other door-mounted devices.

(8) The back-panel layout will show the location of all other panel-mounted devices, and will assign a back-panel area for terminal blocks.

(9) The terminal-block layout will show the location of specific terminal locations according to their function, and the locations of spare terminals and unassigned spaces.

(10) The drawings will be those shown in chapter 4 of this manual for the standard HVAC control systems, with site-specific modifications and any additional control-system loops required. The number of contract drawings necessary to show each control system varies with the system size and complexity. Most control systems in this manual can be shown with the schematic, ladder diagram, and equipment on one drawing, and control-panel details on two drawings.

b. The HVAC control-system specification.

(1) Because the HVAC control-system designer has the responsibility to completely design the control system, the specification requires more technical detail than would be required if the designer needed to specify only the end-performance result of control. The performance-type specification approach used in the past allowed the vendor more latitude in the selection of control devices, in the construction of control loops, and in the construction of HVAC control panels.

(2) The designer must now specify more extensive vendor submittal requirements than had previously been required. The submittals required are shop drawings, commissioning procedures, operating and maintenance instructions, training-course documentation, a calibration-commissioning-adjusting report, testing documentation, and a list of service organizations.

(3) The control devices to be used must be specified in detail.

(4) Because the control system is electronic and can interface with various EMCS, the requirements for electrical surge-protection devices installed in the system wiring must be specified, both to protect the HVAC control system and to prevent surges on HVAC control system wiring from adversely affecting the EMCS.

(5) Each control system must have a sequence of operation and a commissioning procedure.

c. Sequence of-operation. Each control system will have a sequence of operation. The sequences will be included in the project specification or they may be shown on the contract drawings. Where the project HVAC systems are similar, the control loops and logic having identical control functions will be described identically in the sequences. The text of the sequences will vary only to the extent necessary to describe the operation of dissimilar control loops and logic.

d. Commissioning procedure. The project specification for each control system will include a commissioning procedure. The commissioning procedure is a four-step process that details how the vendor will inspect, calibrate, adjust, and commission each HVAC control system. The types and quality of calibration instrumentation to be used in the procedure and the extent of documentation of the procedure will be specified. Where project HVAC systems are similar, the requirement for applying the procedure to control loops and logic will be described identically in each procedure. The text of the procedures will vary only to the extent necessary to describe the application of the commissioning procedure to dissimilar loops and logic. The four steps of the commissioning procedure are as shown in table 1-1.

Table 1-1
Commissioning Procedure

Step: 1. **Activity:** System inspection. **HVAC-system condition:** Shut down. **Purpose:** Observe system for position of valves and dampers, and readiness of HVAC control panel.
Step: 2. **Activity:** Calibration accuracy check. **HVAC-system condition:** Shut down. **Purpose:** Collect one data point for each sensing element, transmitter and controller combination under steady-state conditions.
Step: 3. **Activity:** Actuator range adjustments. **HVAC-system condition:** Shut down. **Purpose:** Set full-stroke travel of actuators matched to controller output range.
Step: 4. **Activity:** System commissioning. **HVAC-system condition:** Operating. **Purpose:** Collect second data point for calibration accuracy check, tune controllers, observe control of HVAC system in each mode of operation, and observe the operation of safety devices.

1-10. Control-system Interface to EMCS

a. Transmitters and control point adjustment (CPA). The control-system design will show HVAC control-panel terminal blocks showing installed jumpers for interfacing control-system transmitters with EMCS. Removal of these jumpers allows EMCS to connect devices in series with the 4- to 20-milliampere current loop. The EMCS devices read the HVAC transmitter signals to the HVAC system controllers. Terminal blocks that allow connection of the single-loop digital controller's remote-setpoint input to a CPA signal from EMCS will be shown. For information on EMCS reference TM 5-815-2.

b. Status and shutdown devices. Low-temperature-protection thermostats, smoke detectors, and high-static-pressure shutdown switches operate relays in the HVAC control-system logic to perform the required control functions. Contacts of these relays are wired to terminal blocks in the HVAC system control panel for EMCS use. Differential-pressure switches in the air-handling-system filters will have a contact in the device reserved for EMCS use.

c. Override of HVAC control systems by EMCS. The control-system ladder diagrams and HVAC control-panel details will show provisions for:

(1) Replacing HVAC control-system time clocks by EMCS start-stop contacts.

(2) Installing an EMCS override of the HVAC system's economizer-mode controller signal.

1-11. Fan-starter control-circuit override by external control systems

The ladder diagrams for fan-starter control circuits will show provisions for shutting down the fans and for overriding low-temperature safety thermostats and smoke detectors to start the fans from external systems. These provisions are intended to allow interface with smoke-control systems.

1-12. Coordination with HVAC system balancing

The project specification will require that balancing is completed, that minimum damper positions are set, and that a balancing report is issued before control systems are tuned. Other control-system commissioning activities may be performed independently of HVAC system balancing.

1-13. Explanation of Terms

Terms, abbreviations and acronyms are shown in the glossary, section I.

1-14. Symbols

Standards symbols used in this manual are shown in the glossary, section II.

1-15. Figures

All figures are located at the end of each chapter.